HARBOURS IN GREENLAND

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1. DESCRIPTIVE DATA

Greenland is the largest island in the world and a province of Denmark.

Geographical Position and Extent

From 59°46' N.lat. to 83°39' N.lat., 2,670 km.
From 73°08' W.lon. to 11°39' W.lon., 1,050 km.

Coast Line

Total length 39,000 km.

Area

Total area		2,186,000 sq. km.
Icecap	appr.	1,844,300 sq. km.
Ice-free area		341,700 sq. km.

Elevation

Icecap, maximum elevation appr. 3,300 m
Highest mountain peak 3,733 m.

Water Depths

In the Davis Strait and Baffin Bay 2,000 - 3,000 m.

Population

In 1968 Total population	45,639
Distributed on:	
Towns	32,745
Settlements	12,894

2. CLIMATE - ICE CONDITIONS - TIDAL RANGE - NAVIGATION

The Climate is variable and sharply contrasting. In South Greenland it is affected by the mild and turbulent Atlantic Ocean, which with its depressions cause heavy precipitation, frequent winds, extreme weather and temperature changes, and frequent fogs produced by field ice.

North Greenland is under the influence of the Arctic Ocean.

The heavy fluctuations in temperature over the year follow a well-shaped curve of continental character, generally with calm weather conditions and no great variations.
At Prins Christian Sund (near Cape Farewell) the average temperature for the year is about 1° C. - at Station Nord 81.5° N. lat. it is 18 degrees lower.
In 1965 Upernavik, 72°77' N. lat., had average temperatures of - 2o° C. and + 6° C. for the coldest and warmest months of the year, the lowest and highest recorded temperatures that year being - 29° C. and + 16° C. Narssaq, 6o°54' N. lat., average temperatures coldest and warmest months - 6° and + 9°, lowest and highest recorded temperatures - 18° C. and + 19° C.
The storm frequency is high, and extreme wind velocities have been recorded. During a storm at Angmagssalik in February 1970 the anemometer bottomed, estimated speed 165 knots.
The wind load is, therefore, essential to constructions, and the wind may disturb navigation.

Ice Conditions
You distinguish betwween polar ice, drift ice, fast ice, and glacier ice.

The Polar ice is carried by the Greenland Current from the Arctic Ocean down along the east coast of Greenland to Cape Farewell and from there north along the southwest coast of Greenland. The amount of ice varies according to the season. The polar ice is rarely carried further north than Godthåb. West Greenland is usually free of polar ice from August until the arrival of the new polar ice about January.

The Drift Ice comes from Ellesmere Island and Baffin Island and is carried by the ocean current into Baffin Bay and the Davis Strait. From October and a couple of months ahead it obstructs the northwest coast of Greenland.
Contrary to the polar ice the drift ice is a one-year ice (the polar ice about 5 years).

The Fast Ice is formed in the fiords and along the coast during the wintertime. From Egedesminde and north the harbours are closed by fast ice for about six months every winter.
From Sukkertoppen to Holsteinsborg navigation may be obstructed by fast ice, which, however, often may break up.
From Godthåb going south fast ice is a rare phenomenon around towns, but it may obstruct navigation within the fiords.

Glacier Ice is produced by glaciers calving at sea level. Most of the ice, derive from West Greenland, especially from the area Jakobshavn and Northward.
From East Greenland glacier ice is also carried round Cape Farewell up along the coast of South Greenland.
Calving from the glacier at Jakobshavn produces about 1.0 m seiching in the Jakobshavn harbour.

Tidal Range

Godthåb has the largest tidal range (5.1 m) and it grows smaller as you go south or north.

Greenland Navigation

Navigation along the east coast is only possible during a short season, and only with craft specially built for arctic conditions. Danmarkshavn e.g. is open for about 5 weeks only, August-September.
The west coast up to and including Holsteinsborg is open to navigation all the year round, but during certain periods navigation around Nanortalik, Julianehåb and Holsteinsborg requires specially built craft.
The area from Egedesminde to Upernavik is closed to navigation for 5 - 6 months and Thule for about 8 months.

3. GREENLAND HARBOURS

General Information

Goods are transported to Greenland and distributed along the coast by sea. Considering, moreover, that the main industry is based on the marine fisheries, harbour facilities are of vital importance to the social economy of Greenland.

In the past no great demands were made in this respect. The hunters could easily pull up their boats and kayaks on the shore, and from the time of the first colonization vessels have been loaded and unloaded by lighters to shallow-water quays, while taking advantage of the large range of tides. This situation prevailed until the early 1950's when the Creenland Commission recommended the development of the Greenland community on a scale which required essential improvements of the harbour facilities. To illustrate developments since then it may be mentioned that total transport of goods to Greenland in 1950 was 51,000 tons against 15o,ooo tons in 1969.

Commercial Harbours

With the exception of Godhavn and Christiabshåb all towns from Nanortalik to Jakobshavn have quays for oceangoing vessels.
At Nanortalik and Narssaq there are facilities for vessels up to 500 GRT only, but larger quays are under consideration. The other harbours have quays which, all according to local conditions, can accommodate vessels up to 3,000 - 7,500 GRT, and this is also the target figures for the quay for transatlantic vessels planned at Christianshåb.
The only such quay on the east coast is at Angmagssalik.

Fishing Harbours

The development of regular industrial plants has been concentrated on the open-water towns: Frederikshåb, Godthåb, Sukkertoppen, and Holsteinsborg, where canneries have been established. These towns have quays for large cutters and trawlers.
In the Disko Bay large shrimp factories have been established at Christianshåb and Jakobshavn and also quays to accommodate shrimp cutters of from 20 - 40 GRT.

Future Requirements

Throughout the past the harbour construction programme has been adapted to the shipping policy adopted by the Royal Greenland Trade Department. From 1972 the transport of goods will be handled by unit-load vessels. The vessels in question are 98 and 140 m in length, and of 5.7 m draught, and efforts will be made to accommodate this system through forthcoming developments of the harbours and the adjoining back areas and also the warehousing facilities.
Within the fisheries the trend is towards larger cutters and trawlers with a view to participation in the all-seasonal fisheries on the Banks.
In recent years the establishment of facilities for pleasure craft has also come up.

Location of Harbours and Choice of Structure.

The harbours in Greenland have all been located so as to benefit from the natural shelter offered by skerries and island groups or directly in a natural harbour.

Because of the deepness of the sea at the shore none of the harbours have been built in the traditional way with an outer and an inner harbour protected by moles but breakwaters have been established between island groups or as a partial enclosure of natural basins. Most harbour installations thus comprise quays built in naturally sheltered areas, with due consideration to the possibilities for inclusion of back areas. The construction cost for quays is very high in Greenland; because of the ice, constructions must be solid, and because of the tidal range, they must be high, and apart from this the topographic features are usually unfavourable.

The harbours are, therefore, on a rather small scale, and most of the quays for ocean-going vessels are no more than 60 m in length and about lo m deep at mean sea level.

The installations are not meant for towboat service.

The first large quays were established by means of timber caissons placed on levelled seabottom. More recent constructions have consisted of front walls anchored at upper and lower level either in the form of sheet piling with sand fill or more open timber constructions with rubble fill.

There is seldom any direct possibility of driving a front wall into the bottom, and it is therefore necessary to secure the wall at the bottom by means of anchors or blasting of trenches or drilling of holes for front piles.

In recent years som quays have been built in the form of a cellular sand-filled underwater structure of steel to about sea level with a timber superstructure with rubble fill.

When called for by local conditions, the interlocking steel sheet piles in the cellular structure are driven into a bed of pumped in sand.

4. EXPERIENCE GAINED FROM THE USE OF STEEL, CONCRETE AND WOOD IN PORT ENGINEERING IN GREENLAND.

To begin with it should be noted that our experience is not based on scientific research but on more or less spontaneous control of materials used in structures both of an older and of a more recent date.

Steel

Basic Conditions. - At the low temperatures prevalent in Greenland the chemical action, including the rusting of unprotected steel, proceeds more slowly than at higher temperatures.

In harbour constructions the rate of corrosion - and thus also the lifetime of the material - are, however, even more dependent on the changeable action of oxygen and salt water as effected e.g. by the tidewater.
It is our experience from Greenland that harbour structures of steel rust just as rapidly here as they would in warmer climates. Therefore, they need the same protection as elsewhere.

Anticorrosion Protection. - Piles and members of steel e.g. are protected by conventional means, ranging from plain asphalting, which by the way is not considered to offer any actual protection against rust, to coal-tar epoxy, painting and galvanizing of the piles. Cathodic protection has not been used, but the more recent steel structures have been prepared for future protection by this method.

Construction Details. - Efforts are made to avoide the use of steel within the tidal zone, by building the superstructure of timber, which has better keeping properties than steel, especially in the tidal zone, and the foundation, which generally is always fully submerged of steel. This e.g. is the principle adopted in the construction of the newest quays at Holsteinsborg. Besides, it provides for good and safe draining of the quay structure so that in the calculations it is only necessary to allow for a small water pressure differential.

Anchors. - Another special point in cennection with the quays in Greenland is the anticorrosion protection of the anchors where rubble has been used as fill. These anchors are galvanized and subsequently protected against injury from the rubble by two windings of asphalted jute. Anchors embedded in sand are as a rule not protected against rust, for the sand reduces the detrimental effect of the changing water level i.e. the alternating effect of oxygen and water on the steel.

Steel. - It is important to use steel guaranteed against cold-shortness at temperatures so low as those to which the structure may be exposed; this applies in particular to the steel for the anchors. In spite of the static load conditions experience from a quay at Frederikshåb shows that anchors may break at low temperatures due to the cold-shortness of the steel. Moreover, it should be mentioned that anchors embedded in rubble are exposed to further and unpredictable actions, not only during the construction phase but also afterwards. Settling of the fill is unavoidable and may result in considerable additional tension in the anchors, a situation which may prove disastrous to the structure if the anchor steel is cold-short.

Concrete.

In connection with harbour constructions the durability of concrete has always given rise to problems of a technological nature.
Generally, it is difficult to obtain a high grade concrete in Greenland due to the below mentioned conditions:

Aggregates. - In many cases the grading of the aggregates is unfortunate as it is necessary for economic reasons to use the local resources of sand and stone from the sea. Unless special care is taken in the grading certain fractions will be missing.
In recent years great preliminary efforts have been made to have the local supplies of sand and gravel registered so that now screening analyses are available for the most suitable sources of sand which makes it possible to mix an workable aggregate. As a rule it is the filler fraction that causes trouble.

Content of Cement

Due to the low average temperatures the setting process is often difficult. This is remedied by the use of a quick-hardening cement in comparatively large proportions. In ordinary concrete structures the minimum content of cement is seldomly below 350 kg/cu.m. concrete and in structures in the tidal zone not below 450 kg/cu.m.
For submerged structures the concrete is always made from a special quick-hardening cement, and the water/cement ratio is always kept below or equal to 0.6.

Working Methods. - To ensure that the concrete sets properly in the tidal zone the water used in the mixing and also the aggregate are heated, for even in summer the temperature is always low, about + 2° C.

Agents. - Air-entraining agents and vibration are always used in the mixing of concrete.

Inferior Quality of Work. - It has been experienced that in the tidal zone the durability of the concrete has always been low. Peeling and frost-cracks are observed frequently, but examiniation of the structures has proved that in cases of pronounced deterioration this may usually be blamed on inferior quality of work, including also a too low cement content and aggregates of poor grading.
Finally it may be mentioned that because of the dry climate in Greenland great care must be displayed to keep the newly cast concrete watered and covered.

This applies in particular to concrete work within harbour areas and fish processing plants where the finished concrete surface is exposed to heavy loads and chemical action of different kind.

Wood

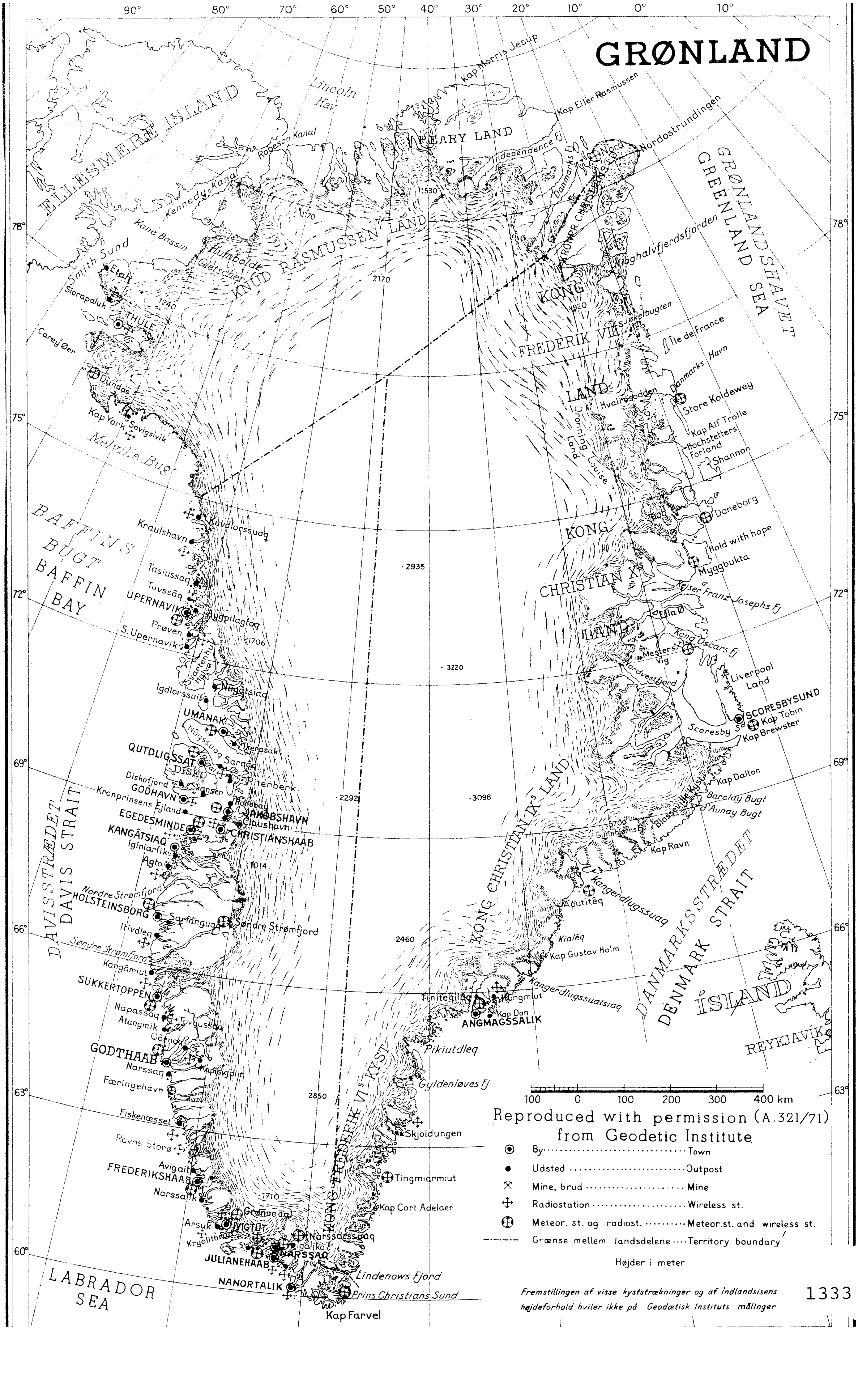
Traditionally wood and stone have been the materials most commonly used in Greenland for building purposes, including also the construction of harbours.

The wood available was spruce and pine, and because of the dry, cold climate which counteracts dry-rot, the structures have been fairly well-preserved.

Spruce and Pine. - The strength of the wood as compared to its weight and its fine workability still makes it an important building material in Greenland.

Experience from the use of wood in harbour constructions have been good even though unprotected timber cannot be used because of gribble attacks (Limnoria Japponica). All timber from the common fir is therefore being impregnated with an arsenical before it is used in harbour structures, to make it proof against rot and gribble attack.

Hardwood. - Because of the increasing demand for larger depths of water it is necessary in the construction of quays to use hardwood such as Azobé, Basralocus and Greenheart which because of its strength and long dimensions can compete in price with steel. These hardwood structures have proved very durable in areas where there is no risk of damage caused by ice.


GRØNLAND
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Kap Morris Jesup
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GREENLAND SEA
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KONG FREDERIK VIII's LAND
Dronning Louise Land
KONG CHRISTIAN X's LAND
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BAFFIN BAY
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REYKJAVÍK
LABRADOR SEA
Kennedy Kanal
Robeson Kanal
Kane Bassin
Smith Sund
Humboldt Gletscher
Melville Bugt
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Tuvssâq
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d'Aunay Bugt
Kap Dalton
SCORESBYSUND
Kap Tobin
Kap Brewster
Scoresby Sd.
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Nordvestfjord
Mesters Vig
Kong Oscars Fj
Ella Ø
Kejser Franz Josephs Fj
Myggbukta
Hold with hope
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Shannon
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